Bernhard Riemann's life

George Friedrich Bernhard Riemann, or Bernhard Riemann, was born in 1826 in Breselenz in what was the kingdom of Hannover, which is now Germany. His father Friedrich Bernhard Riemann was a poor Lutheran minister who participated in the Napoleonic wars. His mother Charolette Ebell unfortunately died before any of her children reached adulthood. Riemann was the second of six children, one of only two boys. Although the family suffered from a variety of misfortunes, mainly being poor and of bad chronic health, they were still very close and held good relationships with one another.

From a young age, Riemann showcased an impressive level of mathematical skill which sometimes even surpassed the skill of some of his teachers. Riemann and his six siblings received their elementary education from their father, who later received some help from a local teacher. Generally a good student, Riemann was actually extremely timid, had a phobia of public speaking, and suffered from chronic health problems that would ultimately cause his early death. When Riemann was fourteen years old, he attended the Gymnasium in Hanover, where he had unlimited access to the library and time to read as many mathematical texts as he desired. During this time, Riemann lived with his grandmother, but when she died two years later, he moved to the Gymnasium in Lüneburg, which was very close to Quickborn, the town Riemann’s family had moved to temporarily to be able to keep the family close.

Under the influence of his father, Riemann attended university to study theology and philology in 1846. In the environment of the university, Riemann began to grow more interested in philosophy, and with his father’s approval, he transferred to study philosophy, which included mathematics in its teachings. Some of his teachers in the Faculty of Philosophy were Carl Friedrich Gauss and Johann Benedict Listing. Later, in 1847, when Riemann’s father was in a stable economic state, Riemann was able to transfer to the praised Berlin University. At Berlin University, Riemann’s teachings were much more stimulating due to the presence of Carl Gustav Jacob Jacobi, Johann Peter Gustav Lejeune Dirichlet, Jakob Steiner, and Gotthold Eisenstein. Because of these great minds, many concepts, such as number theory, geometry, and real analysis Abelian functions, were very well understood and represented; in this setting Riemann received the bulk of his influence and inspiration. Following his fathers wishes, he returned to Göttingen University in 1849, where he slowly received higher positions until he eventually became the head of the mathematics department in 1859.

On June 3, 1862, Riemann married Elise Koch with whom he had one daughter. In July of 1862, Riemann had an attack of pleuritis, and although he recovered slightly, his health only declined from that day forward. To try to cure his illness, he went to the warm weather of Italy periodically. In Italy, he took up an interest in art and tourism around the country. He also visited mathematicians in Italy, mainly Betti, whom he had known from Göttingen. Riemann went back and forth from Göttingen to Italy the last few years of his life, ending the trips in Italy. On June 16, 1866, Riemann arrived in Selasca, and a few days later passed away, while his wife read the Lord’s Prayer for him. He was then buried in the cemetery of Biganzole. The cause of Riemann’s death is not completely clear. Some speculate that he died of consumption caused from the attack of pleuritis, but others believe the true cause was tuberculosis, for his mother, his brother, and three of his sisters all died from the disease long before.
Bernhard Riemann’s mathematical works

Bernhard Riemann is a name that should be as household as Einstein. One of the most commonly used formulas in calculus, the Riemann sum or Riemann integral, is named after him because he made its use so extensive. To anyone that is more involved with mathematics than the every-day person, the name Riemann should quickly bring up the thought of a huge mathematical mystery.

This Mystery is known today as the Riemann Hypothesis. Riemann studied an equation which was explored by Leonhard Euler a century before, known as the zeta function which states:

\[ \zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} \]

Riemann took the function further and began working with complex numbers which include imaginary numbers where \( i = \sqrt{-1} \). Through his studies of this function, he conjectured the Riemann Hypothesis. The hypothesis states, in basic terms, that all the non trivial zeroes of the function lie on a line, the line being \( x=1/2 \). Unfortunately, since Riemann lived a short life, he was unable to continue working on his hypothesis and it became the last problem he ever tried to work on. Today, many mathematicians are working hard to find the answer to the Riemann Hypothesis. Such a discovery would be revolutionary in the understanding of prime numbers as well as aiding in areas such as cryptography.

Although Riemann is known mostly because of his Riemann Hypothesis, that does not come close to describing everything he had ever worked on. His work on complex analysis led to what is now known as topology, or the study of surfaces. General relativity, one of the most famous physics changes in all time was made possible because of Riemann’s work; specifically the Riemann Tensor is an equation frequently used when studying general relativity.

Another very important work from Riemann’s mind is the analysis of manifolds, or Riemannian Geometry. Riemannian Geometry is the study of curved surfaces. In regular Euclidian space, we have simple equations to compute the area inside a circle, the area inside any shape for that matter, as well as perimeter circumference and many other standard geometrical principles. In Riemannian Geometry, the space is no longer Euclidian (flat and three dimensional) the space now encompasses curves as its surface planes and all equations and computations must include how much stretch the plane has in one direction or another. Working mainly in what is known as Ecliptic space, the Riemannian geometry had applications that Riemann likely never thought possible. When most mathematicians work, the formulas and equations they are finding don’t always have an immediate application. This workflow, although seemingly senseless, has created a vast collection of equations and functions that have found use in other fields of study such as physics. Riemannian geometry was especially important in changing how the world views exactly the way things around us work. This was achieved by Einstein’s Theory of General Relativity. Before explaining the universe under the terms of General Relativity, Einstein extensively studied Riemannian geometry, and then applied it to how space exists. Through his understanding of Riemannian Geometry, Einstein formulated the idea of space-time as the general membrane for the universe and showed how both time and space themselves can become curved. Because of how Riemann described surfaces of curved space, it is easily possible to calculate things like gravitational lensing, which is an optical effect that happens when a very massive object passes in front of a bright light.

Riemann is a name that is not as recognized as it should be. With such extreme developments as well as being known for giving one of the most important mathematical speeches in time, Riemann is easily one of the most under recognized mathematicians. Without the work of Riemann, we would never have General Relativity, and we would not have such a good sense of topology, or higher dimensions as we do now.
Collaboration with other scholars

The first mathematicians that Riemann worked with were Johann Carl Friedrich Gauss and Moritz Stern. Due to the Göttingen having a very elementary mathematics department, Gauss was unable to recognize Riemann’s talent. Later, when Riemann went to study in the University of Berlin, he studied under Jakob Steiner, Carl Gustav Jacob Jacobi, Ferdinand Gotthold Max Eisenstein, and Johann Peter Gustav Lejeune Dirichlet, Dirichlet being Riemann’s main source of inspiration. Later, when Riemann returned to Göttingen, he went under the supervision of Gauss, but Gauss was not the only one who made him work harder. Wilhelm Eduard Weber and Johann Benedict Listing, who also returned to Göttingen around the same time Riemann did, also strongly influenced Riemann’s career.

Much of Riemann’s work consisted working off of previous works. For example, to create what we now know as Riemann Surfaces, Riemann worked off Augustin Louis Cauchy’s foundation of complex variables and off Victor Alexandre Puiseux’s ideas of branch points. Because Riemann worked with such complex concepts, the majority of the mathematics world didn’t recognize the genius of his work. As a result, once Riemann became a professor, very few people attended his lectures. One of the few students who attended the lectures was Julius Wilhelm Richard Dedekind, who unlike most other people at the time was able to appreciate and understand Riemann’s work. Dedekind went on to create the eta function which is used to describe the upper half-plane of complex numbers where the imaginary part is positive:

$$\eta(\tau) = e^{\frac{\pi i \tau}{12}} \prod_{n=1}^{\infty} (1 - q^n)$$

In 1858 Francesco Brioschi, Felice Casorati, and Enrico Betti all visited Göttingen to talk to Riemann about ideas in topology. From these conversations, it was apparent that Betti and Riemann both profited from each other more than the others, and this relationship was made stronger when Riemann visited Betti in Italy in 1863. Betti and Riemann collaborated from then on to develop the ideas of topology until Riemann’s death.

In 1859, when Dirichlet died, Riemann was appointed to head of the mathematics department, only to be elected a few days later to the Berlin Academy of Sciences. He was appointed by Karl Theodor Wilhelm Weierstrass, Carl Wilhelm Borchardt, and Ernst Eduard Kummer, all of whom recognized Riemann’s genius and wanted others to recognize it as well. Unfortunately, due to the accelerating deterioration of his health, Riemann was unable to communicate well with too many other people, except the most influential of his colleagues such as Gauss and Betti.
Historical events that marked Bernhard Riemann’s life

Riemann is considered a German mathematician, although Germany did not become a country until after his death, in 1871. Before then, the area that is now known as Germany was a large combination of small kingdoms which were all under the Holy Roman Empire. By the 19th century, the Habsburgs had the title of rulers of the Holy Roman Empire as well as Austria, but with the rise of Prussia the Habsburgs were left with little power over the Holy Roman Empire, which by then was hardly a title. Through annexation and general assimilation, the number of German empires was vastly reduced by the beginning of the 19th century. This was also a time when Europe was dealing with the Napoleonic Wars, in which Riemann’s father participated, and Germany, due to its central location, suffered from a high amount of military action. At the end of the Napoleonic wars, Germany was granted a small amount of land which Napoleon had taken a few years back.

Then, in 1806, Prussia felt threatened by France and declared war on them. This didn’t go well for them, as France was quickly able to defeat the Prussian military. Napoleon then took some of the German land, including two new empires and gave one to his brother and one to the King of Saxony. To gain a better image among the various German states, Napoleon elevated the status of many of the rulers, and gave them more land. With this rearrangement of power and land, the Confederation of the Rhine was created, so the Holy Roman Empire was no longer needed, and Napoleon forced the Habsburgs to give up their title.

The majority of German states joined the Confederation of Rhine, all except Austria, Prussia and two other minor states. Being part of the Confederation meant that those states would be highly exposed to the ideas of the French and American revolutions. This came with radical changes throughout the states. Serfdom was abolished, and nobility lost many privileges while the general public gained many, like freedom of press and freedom of religion. The economy also tried to shift to a more capitalist economy, but this was met with more resistance than the rulers had thought, and they were never able to implement it.

Shocked by their quick defeat, Prussia decided to set their priorities straight. They began to modernize their military, creating a national guard and changing the officer corps from being exclusive to nobles to being open to anyone willing and educated. Pay was determined by how much someone worked, and with the abolition of serfdom, many class specific privileges had been taken away, and land ownership was available to all.

After Napoleon’s defeat in 1813 in Russia, Prussia decided they were ready to take Napoleon once again. Allied with Austria and Russia, Prussia easily defeated Napoleon, and continued to play a significant role in his descent. The Confederation of Rhine fell apart after the war, and some members deserted Napoleon. After Napoleon’s defeat in 1815, the German Confederation was formed to promote trade and provide protection to the German states. Most German citizens looked forward to this new society with a lack of class specific privileges and a rise of German nationalism resulted.

Unfortunately, the major powers, Austria and Prussia both wanted to see the German states go back to how they were before Napoleon. The leaders of the individual German states feared Nationalism because they knew it meant losing their power, especially Austria, which was composed of a variety of ethnic groups. Other groups, like nobles and artisans, feared change because they knew it would mean losing their privileges and power. Because of these various views of change, it was slow or nil during these years. Eventually, the Nobles lost their privileges and hard to learn how to live with a more progressive society. This was also a high time for the Industrial Revolution, which meant that many small home based businesses were taken down due to their work no longer being needed. This also lead to urban sprawl, which brought many of the diseases from outside the cities. Then, in 1834, the German Customs Union was formed, which smoothed out trade and standardized the three currencies used in Germany at the time. With Austria left out, Prussia was able to close their ties with the German states. Even with all this seemingly good progress, there was still a lot of bad things going on. Many farmers were forced to live off too little land, and serfs, being granted freedom, had to compensate with land they didn’t have. Because of new illnesses and the lack of jobs, many left to go to the
United States to seek a new life.

Then, in 1848, Europe in general felt a surge of revolution. With the ideas of the French and American revolutions sitting in many peoples’ minds, many changes were wanted by the people. A German National Assembly was formed in order to figure out a German parliament and a unified Germany. On March 28, the delegates of Frankfurt sent a message to the Prussian king, electing him as emperor of Germany, which he turned down because he didn’t need their help. Because of this, the revolutionary period did not last long. Most of the rural citizens paid little to no attention to the revolution, and the leaders of the revolution had turned against each other in their debate of which direction to take the revolution. The German National Assembly was ignored by the German rulers, and Prussia was soon able to regain control of the German states and use military power to subdue any resistsors.

The biggest issue at this time was whether Austria or Prussia would gain power over the German states. In an attempt to gain more power, Prussia invaded two independent duchies from Denmark, but international pressure made Prussia retreat. With the death of the Danish king, and a lack of male heir, a non-trustworthy king was appointed. As a result, the German Confederation decided to take action, and with the help of Austria, Prussia took over the two duchies. This was not the best move, since Prussia and Austria would both be unable to decide on a way to separate the new territories, especially with the new prime minister of Prussia, Otto von Bismarck, who was determined to see Prussia become the main leader of the German states.

On June 15, 1866, Saxony, Hanover and Hesse-Kassel refused to give Prussia assurance of their neutrality, and the Prussian military invaded, beginning the seven weeks’ war, which decided the fate of the future German states. Austria’s quick defeat can mainly be traced to Prussia’s innovation the years before. While the Austrian Army was doing things the old fashioned way, the Prussians were using preloaded rifles and much better and faster transportation to be able to defeat the Austrians. Prussia, having won so many small battles throughout the area, made an armistice by the end of July, and a treaty was signed August 23, 1866, giving control of the German states to the Prussian Empire.

With the quick rise of the Prussian Empire, the French felt threatened and attempted to control the Prussian rise of power, but like the Austrians, they were met with defeat, although the defeat didn’t come immediately. On October 7, 1870, a minister left Paris and landed outside Germany to attempt to create guerrilla warfare, slowed down the progress of the Prussian Empire, but ultimately Prussia went on to gain power. In early 1871, delegates from Paris crossed German lines to Versailles where they met the excited Prussians, who five days earlier had seen their Prussian king become emperor of Germany.
Significant historical events around the world during Bernhard Riemann’s life

The 19th century was a time of high activity around the world. In this century came the collapse of many large empires, including the Holy Roman Empire, the Spanish Empire, the First French Empire, the Chinese Empire, and the Ottoman Empire. With the decline of these empires, others could grow, including the German empire, the British Empire, the Russian Empire, the Japanese Empire and the United States. With power rising in so many different places at the same time, there was a lot of tension between the rising powers; this increasing conflict went on to shape the rest of the century.

1820-1830: Early in the 19th century, after the Vienna Congress in 1815, Europe thought that they were going into a time of stability. Unfortunately, this did not last and in 1821, Europe soon began to erupt into instability. Later that year, Napoleon died in the island of St. Helena. A treaty was signed between the US and Spain which gave the US the Florida territory. After this loss, many of the Latin American counties declared independence from Spain. Around this time, Michael Faraday began his work on the unification of electricity and magnetism. In 1822, in Vienna, the accordion was invented. In 1824 in Britain, the Royal Society for the Prevention of Cruelty to Animals was created, the first organization against animal cruelty. In 1826, the Spanish Inquisition was revived when King Ferdinand VII returned. In 1827, thousands of mourners gathered in Vienna to attend the burial of Beethoven. When Charles X became king of France, he was met with very negative opinions from the majority of the working class, and he eventually retreated back to Britain, and France re-implemented the progression Charles X had tried to stop. In 1830, President Andrew Jackson signed the Indian Removal Act, making all eastern Native American tribes move to the west side of the Mississippi river.

1831-1840: In 1831, Charles Darwin completed his B.A. at Cambridge and left on the H.M.S. Beagle to travel to South America, New Zealand, and Australia. In Jamaica, Sam Sharpe, a Baptist, organized a strike in Jamaica around harvest time; unfortunately when the strike unexpectedly turned violent, Sam was the one blamed. With the recent defeat of the Ottoman Empire from the Russians, the Egyptian Empire took advantage and declared independence. As Britain’s Slavery Abolition Act went into play in 1834, the British government prepared to compensate for the people who no longer owned slaves. The Queen Mother, Maria Christiana, the fourth wife of Ferdinand VII, ended the Spanish Inquisition. In 1835, Britain made vaccinations mandatory for all citizens. The southern states of the US expelled abolitionists and made mailing anti-slavery literature illegal. In 1836, Pope Gregory XVI banned railways and modern technology in his Papal States, calling the technology evil and satanic. In 1837, the British asked France and the US to join to patrol international waters for possible slave boats, but the US declined. In 1838, the Cherokee were forced off their farm in what would later be known as the Trail of Tears. Charles Darwin began to develop his theory of evolution and at the same time, there was heated debate about cellular division. In 1839, when the British claimed land that the US had also claimed, small armies from both sides were sent in but since neither side wanted war, a treaty was created three years later which would solidify the border between the US and Canada. In 1839, the US government took custody of a slave ship which had been taken over by slaves attempting to sail it back to Africa.

1841-1850: In 1841, the US Congress decided that the people found on the ship who were trying to return to Africa, were not slaves and were therefore free to return to Africa. With the invention of a time-delay mechanism, the French were able to launch projectiles in a much safer manner for them, a mechanism that the US and Russia would have by the end of the decade. In 1843, Britain banned gibbeting, displaying bodies of the executed to discourage crime. In the US, Charles Thumper invented the typewriter. In 1844, Australia passed a law which would make it legal for church missionaries to kidnap aboriginal children and “civilize” them. In 1845, due to the rising speed of transportation of goods such as the potato from the US to Europe, new potato diseases were introduced to the Irish potato crop, causing what we know now as the Irish Potato Famine. In 1846, when Pope Gregory died, the new pope, being much more progressive than Gregory, decided to introduce railways and gas streetlights. In 1848, Karl Marx, with the help of Frederich Engels, wrote what is now known as the Communist Manifesto. In the summer of 1848, the European economy which had been
suffering the years before began to take a positive turn. The gold rush began in California, and a group of women from New York called for equal treatment of men and women. In 1850, the US passed another Fugitive Slave Act, which many people in the northern states protested loudly.

1851-1860: In 1851, Herman Melville’s Moby Dick was published; Herman wanted to see a rise in giving meaning to the small things in life. Later, in 1852, Uncle Tom’s Cabin was published and many of the southern states proclaimed that the book was highly exaggerated. Owning a copy in the south became illegal. In 1853, Napoleon’s nephew Louis-Napoleon was declared Emperor Napoleon III and he made what was the French republic into the Second Empire. In 1854, general public health saw a very good turn. Scientist John Snow theorized that cholera could spread through ingesting contaminated water or food. Many of his colleagues dismissed the idea, but when a cholera outbreak in London was stopped when Snow took a sample of the water and removed a contaminated water pump, recognition of his thought was finally given. In 1855, Chicago implemented the first functioning sewer system in the US. In 1856, when the Russian Tsar died, his son Alexander II took over and restored good relations with Britain and France. The Crimean wars ended, and with the humiliation of Russia, Alexander sought to reform and change Russia for the better. In 1857, the US Congress ruled against African Americans in the Dred Scott Case, saying that all African Americans, free or slave, had no recourse in federal court. As the second opium war ended, many of the things the Chinese were fighting for were taken away, and they were forced to open ports and allow foreigners to own land. Seeing the new ground for growth, the US and Russia rushed to China to take advantage. In 1859, John Brown attempted to begin a war for the liberation of all slaves, but he was quickly shut down, convicted and hung. After completing his work 21 years before, Charles Darwin published the Origin of the Species. A British scientist John Tyndall proposed that the rising concentration of CO2 and water vapor in the atmosphere may have effects of climate change.

1861-1870: Abraham Lincoln took office in 1861, and the first thing he did was promise the southern states that he did not plan on interfering with slavery, but the paranoia coming from the south eventually changed that promise. On October 26, 1861, the telegraph connected the coasts of the US, making communications no longer reliant on transportation. After a large amount of German mirror makers lost their teeth, Germany began to change the way that mirrors were made. In 1863, Lincoln’s Emancipation Proclamation became a law. In 1864, an astronomer calculated the distance from earth to the sun to be 147 million kilometers, falling short only 2.6 million. In 1865, the US began using hand cranked Gatling guns on the battlefield. While the Civil War was raging on, there were also conflicts with the Native Americans, and commander Colonel Chivington in particular wanted to see the expulsion of all natives. Soon after, the Civil War ended with Robert E. Lee surrendering, and Lincoln’s assassination happened shortly after. In 1866, when a Russian student tried to assassinate Alexander II, the government suddenly saw all students in a negative light and a new minister of education took hold, creating very strict conditions for the students. Trying to seek consolidation on his borders, Alexander II sold the Alaskan territory to the US. In 1867 dating trees by their annual rings began as a custom. In Sweden, Alfred Nobel figured out how to stabilize nitroglycerine, and dynamite was discovered. In 1868, the 14th amendment was ratified, which overturned the decision made about ten years earlier about the citizenship of African Americans. Reconstructed governments in many southern states were established later that year. Joseph Lister theorized that diseases spread with microorganisms, and he reported success that sterilized surgical tools lowered the number of diseased patients after surgery.
Significant mathematical progress during Bernhard Riemann’s lifetime

The 19th century saw a large boom in the progress of mathematics. The main countries to contribute to the progress were France and Germany, due to the recent revolutions around the world.

In France, the main reason for the growth of mathematics was to make the state and military better and more effective, but in Germany the support for mathematics was purely for the sake of mathematics.

Joseph Fourier was one of the first in the century to begin to contribute to mathematics. Fourier’s work consisted of studying infinite sums of trigonometric series, now known as Fourier series. Fourier also worked towards defining what a function meant, although the definition we have today is not what Fourier proposed.

Jean-Robert Argand published a paper in 1806 which explained how complex numbers can be represented on the Euclidian plane, where x is the real axis and y is the imaginary axis, and that they could be manipulated through trigonometric functions as well as vectors.

In the 1820s, a French mathematician named Évariste Galois proved that there is no general algebraic method for solving polynomial equations with degree greater than four. Galois’ work also paved the way for a variety of different mathematical concepts such as abstract algebra, vector spaces and non commutative algebra.

Carl Fredrich Gauss, known by many as the prince of mathematics received his education at the University of Göttingen, where Riemann would study later. Along with Newton and Archimedes, Gauss is considered to be one of the most important mathematicians of all time. Gauss’ work was years ahead of his time, working in the areas of calculus, number theory, algebra and probability, to name a few. Gauss is said to have studied geometries that lie outside the Euclidian apace, but not wanting to cause controversy, he didn’t publish his papers.

This left the doors wide open for Janos Bloyai and Nikolai Lobachevsky to both study non Euclidian space. They began to study spaces that use curvature as opposed to a flat surface. The other mathematician to study these non-Euclidian spaces was Bernhard Riemann. Riemann had a general theory for all types of geometry, but his study of non-Euclidian space went further than anyone had imagined it could go. Instead of considering the functions as being bound to 2 or 3 dimensional space, Riemann began thinking of higher power dimensions such as a 4th dimension and upwards.

A leap in mathematics also occurred in Britain, where the first computer capable of performing complicated calculations was made. Another British mathematician George Peacock did work that largely paved the developments of abstract algebra. George Boole, another British mathematician, devised a completely new way of thinking, in which 1+1=1; Boole’s work is what eventually led to computer science. Then came William Hamilton, whose concept of algebra provided the first example of non-commutative algebra, in which $a \cdot b$ does not always equal $b \cdot a$.

As well as seeing a rise in new mathematical concepts, the 19th century also saw a revisiting of the old techniques and called for more mathematical rigor. During this time, many proofs were given such as a proof for the Intermediate Value Theorem, as well as the Fundamental Theorem of Algebra.

Although Möbius is famed for creating the Möbius strip, he was not the first to imagine such a shape, the name simply stuck with his. Many examples of similar nature arose soon after the introduction of the Möbius strip, such as the Klein bottle, an object that cannot be accurately placed in three dimensional space.

One surprising discovery came from a 16-year-old Italian who found the smallest pair of amicable numbers in 1866, something which had fazed many of the previous great mathematicians like Euler.

Closer to the end of the 19th century, Gerog Cantor established the foundations of set theory, which allowed
rigorous use of the concept of infinity, something that current mathematics uses on a daily basis. A German mathematician, Richard Dedekind, also worked off of Cantor's work and his work defined similar sets as well as infinite sets. Dedekind is also the person we can thank for a continuous number line. He was the first to show that every location on the number line is either a rational or irrational number, with no gaps or holes.

With insight from Riemann's works, the late 19th century saw a rise of two independent theories, both explaining the Prime Number Theorem.

Herman Minkowski, who was a good friend of David Hilbert and also the teacher of Albert Einstein, created a branch of number theory known as the geometry of numbers. It was Minkowski who also realized that Einstein's General Relativity could be understood in a four dimensional space called the Minkowski space-time.

**Connections between history and the development of mathematics**

With all the commotion around the 19th century, an astonishing number of inventions helped to change the way history developed, and listing them all would take quite a while. With the introduction late in the 19th century of the Industrial Revolution as well as the assembly line, the amount of things being created went up exponentially.

Many times, mathematicians or other scientists would work on their own work, but people would later realize that that work would be applied to other areas. The Fourier Series is a perfect example of this situation. Although the Fourier Series was first used to find the solution to the heat equation \( \frac{\partial u}{\partial t} - \alpha \nabla^2 u = 0 \), the series was later found to be applicable to areas such as acoustics, quantum mechanics, econometrics, optics, electrical engineering, physics and mathematics.

A very important invention made in the early 19th century which today is used on a daily basis is the spectroscope. Invented by German glass worker, Joseph von Fraunhofer in 1814, the spectroscope has really changed many different things in the world of chemistry, astronomy and biology as well. The spectroscope is a machine that is used to separate the spectrum of light coming from any given source. This is used to determine what elements compose certain stars as well as anything that gives off light or changes light going through it.

Early in the 19th century there was also a remarkable invention towards the medical industry, the stethoscope. Invented to be able to hear the sounds of the inside of the body better, it was created because the older techniques were not the best ways for trying to listen to those sounds. Where the math comes in with this invention can be traced to the Fourier Series. Since the stethoscope is pure acoustics, the Fourier Series likely helped with making the stethoscope much better than its first iteration.

One invention made in the mid 19th century which truly changed many things about how the world works today is the electromagnet. Invented in 1825 by William Sturgeon, the electromagnet is a fairly simple device which can magnetize a piece of ferrous metal on command. William used the information published five years earlier, which said that electricity can cause magnetic waves, to create his electromagnet and go to show that the more current running though the metal, the stronger the magnet. A few years later, an American inventor called Joseph Henry used Williams discovery to make a stronger electromagnet and through that created the magnetic telegraph.
Photography was another big invention announced in the early 19th century. Although the first picture was announced in 1822, the technologies which were used to make the camera a possibility had been discovered years before. Working with what is known as a camera obscura, Nicphore Nipce used a photosensitive material to capture the light inside the camera to be able to capture the very first picture with recognizable figures. As optics were studied further, many different effects were discovered through the changes in how light is bent, all of which are described with mathematics. For example, the Scheimpflug principle describes the orientation of the plane of focus when the optical plane is not parallel to the film plane. Through the modern understanding of this principle, photographers are able to create pictures with what is known as the tilt-shift effect, or a very peculiar miniaturization effect created with very specific parameters of the Scheimpflug principle.

Electromagnetic waves were one of the last important discoveries during the 19th century. Heinrich Hertz is credited with confirming Maxwell’s theory, which predicted the existence of electromagnetic waves traveling at the speed of light, as well as predicting that light itself is a wave. With the work of Hertz, the photoelectric effect was discovered. This effect describes the observation that many metals emit electrons when photons bounce off of them. Unfortunately, Hertz was unable to find the practical importance of his work, stating that they were of no use and that they only proved Maxwell was right. Little did Hertz know that his discoveries would lead to the invention of the wireless telegraph, audio radio, and even go as far as aiding in the invention of television.

Remarks

Ever since I began to study calculus in high school and learned about the Riemann sum, I had always been interested in him. My interest was boosted when I came across a photographic gallery in Venice. The photographer of the gallery had a manuscript online called “Italy from the fourth Dimension”. In this writing, he talks slightly about Einstein’s work as well as describing what higher dimensions can become when trying to visualize it. Since I have always been amazingly interested in the subject of General Relativity, quantum mechanics and how the world works in general, suddenly finding out that a mathematician I had learned little about helped to create the largest change in physics was one of the biggest mind-blowers for me. The second we received the assignment in class that we had to write a paper about a mathematician, without a doubt I immediately chose Riemann, and I am very happy I decided to study him. Going through his works and finding out about his life has really elevated my respect for him as a mathematician.

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